J. Univ. Kuwait (Sci.) **13,** 1986

Petrography and diagenesis of Quaternary oolitic sediments in northern Kuwait, Arabian Gulf

F. I. KHALAF*, A. A. AL-SHAMLAN** AND M. I. EL-SAYED*

**Environmental and Earth Sciences Division, Kuwait Institute for Scientific Research, P.O. Box 24885, Safat, Kuwait; and **Department of Geology, Faculty of Science, University of Kuwait, P.O. Box 5969, Kuwait*

ABSTRACT

Two ridges of Quaternary oolitic sediments occur in Al-Doha area, northern Kuwait. The first extends in an E–W direction along the coastline and is succeeded landward by a second ridge which is older and rests on pre-Pleistocene deposits. The first (more seaward) ridge is composed mainly of ooids with subordinate proportions of peloids, shell fragments and quartz grains (oolitic limestone ridge). The second ridge is also chiefly composed of ooids but quartz grains and skeletal fragments are much more abundant than in the first ridge (quartz–oolitic limestone ridge). Subaerial cementation was observed in the oolitic limestone ridge, but it is better developed in the quartz–oolitic limestone ridge where the sparry calcite cement increases in crystal size and fills most of the intergranular pores. Some micritic peloids have been almost completely recrystallized to sparry calcite and all the grains are covered by fringes of sparry calcite cement.

The oolitic limestone ridge is correlated with the younger and older oolitic limestones of Al-Khiran area, and the quartz–oolitic limestone correlates with the quartz–oolitic sandstone and oolitic quartzose sandstone of Al-Khiran.

The oolitic deposits of Al-Doha area are diagenetically immature and this can be attributed to insufficiency of meteoric water required to complete the diagenetic development of the deposits.

INTRODUCTION

The Quaternary sediments of Kuwait rest on Miocene to Pliocene deposits of predominantly siliciclastic type. During the Pleistocene, fluvial gravels, locally called the Dibdibba Formation, were deposited in terrestrial areas of Kuwait (Macfadyen 1938) and oolitic sediments accumulated along the coastal area. Detailed descriptions of the Quaternary sediments of Kuwait have been given by Owen & Nasr (1958), Milton (1967), Fuchs *et al.* (1968), Sproule & Associates (1974), Saleh (1975), Picha & Saleh (1977), Picha (1978), Salman (1979) and Khalaf *et al.* (1982b).

Quaternary oolitic and biogenic carbonate sediments have attracted the attention of carbonate sedimentologists since the late 1950's. This was mainly because of their importance in understanding the early stages of carbonate diagenesis and the configuration of facies in littoral carbonate deposits. Pioneer studies were carried out on the Pleistocene limestone of Bermuda by Friedman (1964), Gross (1964), Land (1967) and Land *et al.* (1967); of Florida and the Bahamas by Stehli & Hower (1961), and of the Mediterranean coast by Gavish & Friedman (1969), and Selim (1974).

Although extensive studies have been made on the Recent marine sediments of the Arabian Gulf by Purser (1973), Khalaf & Ala (1980), Khalaf *et al.*, (1982a, 1984), only a few studies have been undertaken on the Quaternary oolitic limestones (Picha & Saleh 1977; Picha 1978).

This paper presents the results of a petrographical and mineralogical investigation of the Quaternary oolitic sediments of Al-Doha area of Kuwait Bay. Their diagenetic history is discussed, and a correlation is made between them and similar deposits near Al-Khiran, along the coast south of Kuwait.

FIELD OCCURRENCES

Al-Doha area is located on the south side of Kuwait Bay (Fig. 1). It is a triangular headland bounded on the east by Sulaibikhat Bay and on the north by Kuwait Bay. Umm El-Namel Island is located close to the tip of the headland. It has developed as a result of coastal erosion along a channel that dissects the eastern part of Ras Ushirij. The area is flat and bordered by a wide intertidal flat which is mostly covered with calcareous crust (cf. reefal flat in Fig. 1). The highest point on Umm El-Namel Island is about 5 m above sea level while a few low hills in Al-Doha Peninsula reach 15 m above sea level.

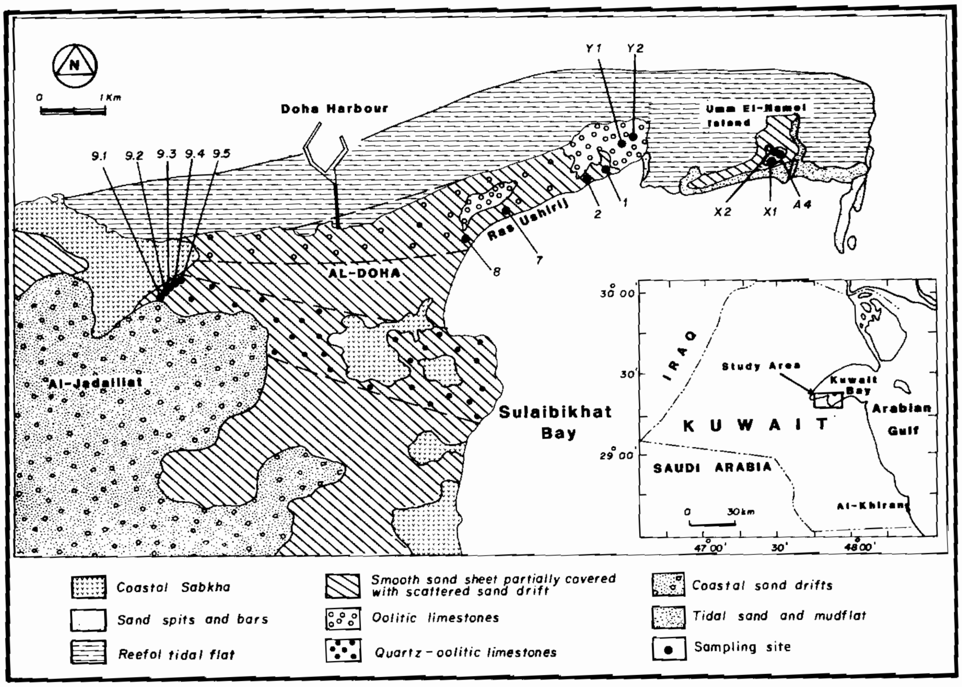

Fig. 1. Geological map of Al-Doha Peninsula.

Fig. 2. Thin-bedded oolitic limestone in Ras Ushirij.

Unlike the southern coastal area at Al-Khiran, where the ridges are long and continuous, the Quaternary oolitic ridges of Al-Doha have been deflated, but remnants remain as small scattered hills. Topography and surface geological features indicate the former presence of two ridges (Fig. 1). The first ridge extends in an E–W direction along the coastaline followed inland by the second ridge which is older and rests on pre-Pleistocene deposits. The two ridges are separated by a lowland area which is covered by a sand sheet and thin sabkha deposits. The first ridge is formed mainly from clean oolitic limestones which are thin-bedded and locally cross-bedded (Fig. 2). This ridge has been subjected to severe wind erosion and is now merely a flat levelled rock surface. The second ridge is built of quartz–oolitic limestones. Its upper part is the most lithified and forms a hard layer of about 0·5–1 m thick. The sediments beneath it are less cemented and have been undercut, resulting in the collapse of the upper hard layer (Fig. 3).

METHODOLOGY

Fourteen samples were collected from three areas on Al-Doha Peninsula namely, oolitic limestone from Umm El-Namel Island and Ras Ushirij, and quartz–oolitic limestone from Al-Jadailiat. The sample locations and sample numbers are shown in Fig. 1.

A representative portion from each sample was prepared and analysed for grain size distribution (Folk 1974). Cumulative curves and histograms were constructed and

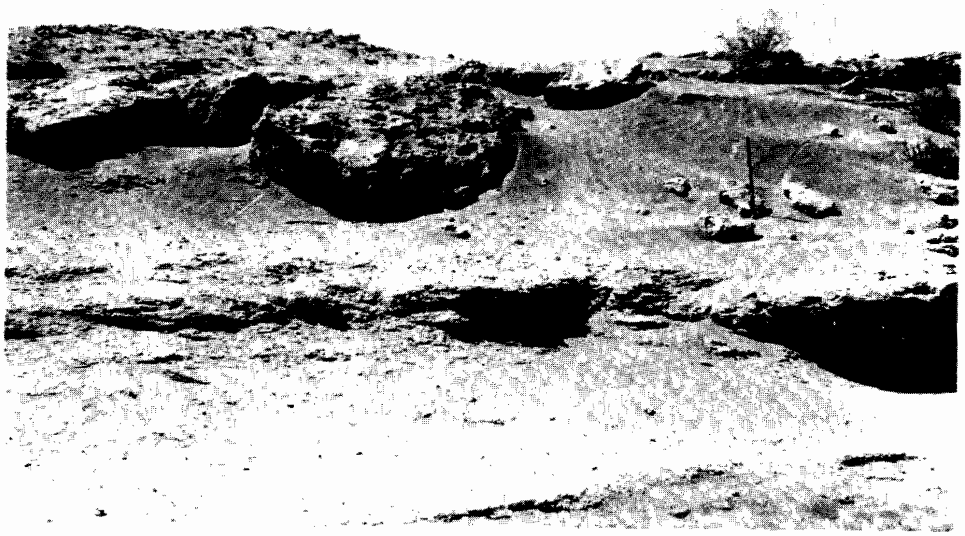

Fig. 3. Caving of the upper layer of the quartz–oolitic limestone due to differential erosion of the less cemented underlying layer, Al-Judailiat area.

statistical size parameters were calculated using the formulae of Folk & Ward (1957). The weight percentage of insoluble residue was determined in each sample by dissolving the calcium carbonate with 10% HCl. In some selected samples the weight percentage of insoluble residues in each size fraction was determined, and the insoluble residues of some selected samples were mechanically analysed.

The relative percentages of the main framework grains in the whole sediment and in various size fractions were calculated by counting a total of 200 grains in each sample. Thin sections were prepared for all samples and studied petrographically. For more detailed study of cement fabric and surface textures of quartz grains, selected samples were examined under a Nova Scan 30 SEM. All samples were analysed by X-ray diffraction to determine the relative abundance of the main mineral constituents (Carver 1971), and were also analysed for strontium using an atomic absorption spectrophotometer.

RESULTS

PETROGRAPHY

The Quaternary oolitic sediments of Al-Doha area are generally composed of ooids, quartz and shell fragments. Table 1 summarizes the results of point count analyses of the depositional components. Two rock types can be distinguished. These are: oolitic limestones and quartz–oolitic limestones (Fig. 4).

Table 1. Relative frequency percentages of (1) the main types of framework grains and (2) insoluble residue in Quaternary oolitic deposits of Al-Doha area, Kuwait

	Oolitic limestones		Quartz–oolitic limestones	
	Range (%)	Average (%)	Range (%)	Average (%)
(1) Ooids	70·0–95	90	38–66	50
Shell fragments	2·5–20	6	5–25	18
Quartz	2·5–10	4	30–38	32
Total		100		100
(2) Insoluble residue	4·0–20	8	23–64	44

Oolitic limestones

The oolitic limestones are composed mainly of ooids, but peloids, shell fragments and quartz grains are present in subordinate amounts. Ooids (Fig. 5A) comprise about 90% of the framework grains. They range in size from 0·18 mm to 0·7 mm; however, about 90% of the ooids lie within the medium sand size range (0·25–0·5 mm). Various types of nuclei are present in the ooids such as peloids of micrite, shell fragments including entire foraminifera and ostracoda, quartz grains, some feldspars and heavy minerals. The nuclei have an average size of about 0·12 mm and the grains are generally coated with micrite. The ooids are mostly spherical with well developed concentric lamellae which range in number from 10 to 30, with the thickness of the oolitic coat between 50 and 180 μm. It was noticed that ooids with micritic peloid nuclei generally have a thinner oolitic coat. In some ooids, the mucilaginous sheaths, which impart the concentric appearance, vary in thickness from one lamina to another and within the same lamina. The oolitic laminae are composed of minute aragonite crystals which have preferred tangential orientation which produces a pseudo-uniaxial figure between crossed nicols (Fig. 5B).

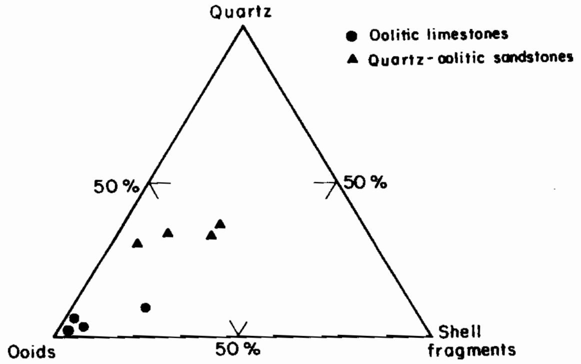

Fig. 4. Ternary diagram showing the difference in the relative abundance of the framework grains of the oolitic limestones and quartz–oolitic limestones.

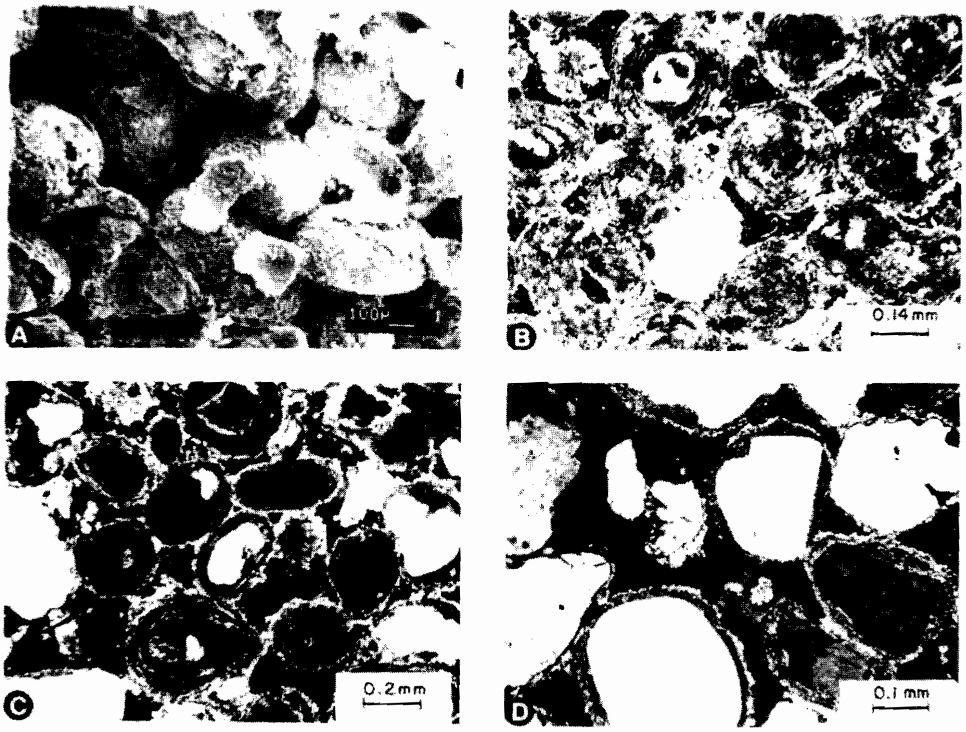

Fig. 5. (A) Scanning electron photomicrograph of the friable porous oolitic limestone. (B) Photomicrograph of the oolitic limestones. Note the pseudo-uniaxial extinction cross shown by the ooids under cross polarized light. (C) and (D) Photomicrograph of the quartz–oolitic limestones. Note the pseudo-ooids and abundance of quartz grains coated with thin micrite envelopes.

Free quartz grains form about 4% of the framework grains, and are present mostly in the coarse sand size fraction (> 0·5 mm) and the fine and very fine sand size fractions (> 0·18 mm). Coarse quartz grains are generally well rounded and frosted while the smaller ones are angular with a vitreous appearance.

The oolitic limestones have relatively low proportions of non-calcareous material. The insoluble residue forms about 8% of the whole sediment and is mostly composed of quartz. The difference between the insoluble residue content and the frequency percentage of the free quartz grains indicates that about half of the insoluble residue content (4%) occurs as ooid nuclei.

Quartz–oolitic limestones

Quartz–oolitic limestones are composed chiefly of ooids and quartz grains, with considerable amounts of shell fragments. Ooids are generally less abundant than in the oolitic limestone. They range in relative frequency from 38% to 66% and are characterized by frequent quartz nuclei (Fig. 5C). The latter range in size from 0·12 mm to 0·35 mm. Ooids with chert and feldspar nuclei are also present. Superficial or pseudo-ooids, which are formed of well rounded quartz grains (0·35–0·5 mm in size) coated with thin micrite films, are dominant (Fig. 5D). In these grains, micritic materials usually cover the irregular surfaces of the detrital quartz grains forming an outer crust similar to that of the ooids. It is difficult to differentiate between these pseudo-ooids and the normal ooids except in thin section. Although the concentric laminae of the oolitic coat in most of the ooids are still preserved, symmetrical extinction is not so clear in these rocks. This might indicate an incipient stage in the change from aragonite to calcite. Partial replacement of aragonite by sparry calcite was noted in some ooids and peloids.

Free quartz grains form about 32% of the framework grains. They form the main constituent of the coarse and very coarse sand size fractions (> 0·5 mm). Quartz–oolitic limestones are also characterized by high contents of insoluble residue, reaching up to 64% by volume and mostly composed of quartz and subordinate amounts of feldspars. Insoluble residues are relatively more abundant in coarse size fractions.

Fig. 6 shows the average relative frequency percentages of the framework grains and average weight percentages of the insoluble residue contents in the various size fractions of the oolitic limestones and quartz–oolitic limestones.

GRAIN SIZE DISTRIBUTION

The calculated grain size parameters of the *whole sediments* of the oolitic limestones and the quartz–oolitic limestones, and the insoluble residues of the latter are given in Table 2. Both oolitic limestones and quartz–oolitic limestones have a mean size of medium sand and are leptokurtic; however, the latter are slightly coarser and less strongly leptokurtic. Oolitic limestones are well sorted and symmetrically skewed whereas quartz–oolitic limestones are moderately sorted and fine skewed. The insoluble residue of the quartz–oolitic limestones has a finer mean size, is less sorted and more platykurtic than the whole sediments.

Fig. 7 shows histograms of the average grain size distribution of the studied sediments.

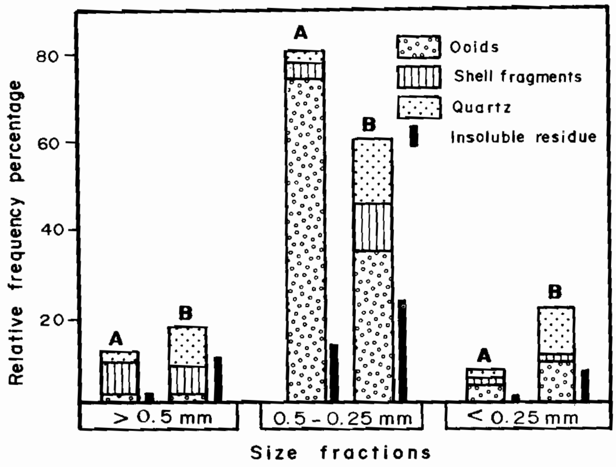

Fig. 6. Relative abundance of the main types of framework grain (ooids, quartz and shell fragments) and wt% of insoluble residue in the various size fractions of the oolitic limestones (A) and quartz–oolitic limestones (B).

Table 2. Grain size parameters of the Quaternary oolitic deposits of Al-Doha area, Kuwait

	Oolitic limestones (whole sediments)		Quartz–oolitic limestones (whole sediments)		Quartz–oolitic limestones (insoluble residue)	
Size parameters	Range	Average	Range	Average	Range	Average
Mean size ($M_z\phi$)	1·30–1·80	1·70	1·30–1·70	1·50	1·30–2·10	1·70
Sorting ($\sigma_I\phi$)	0·41–0·69	0·45	0·64–0·83	0·73	0·62–1·02	0·77
Skewness (SK_I)	0·08–0·17	0·10	0·11–0·38	0·23	0·11–0·20	0·14
Kurtosis (K_G)	1·64–2·54	1·97	1·43–1·91	1·65	0·93–1·34	1·26

CEMENTATION

The main diagenetic feature of the Quaternary oolitic limestone deposits of Al-Doha area is the evidence for subaerial cementation. A gradual increase in the degree of cementation towards the relatively older formations (quartz–oolitic limestones) was noticed, whereas the upper oolitic limestone deposits are generally friable. Ooids are held together with sparry calcite cement which grew along and near grain contacts (Fig. 8A). Investigation of the oolitic limestone using a SEM shows that cementation starts with the development of minute calcite projections on the surface of ooids (Fig. 8B). These projections are usually of pyramidal shape with their C-axes perpendicular to the surface of the grains. Syntaxial overgrowth on these projections leads to the development of subhedral calcite rhombs. Fig. 8C is a vertical view of the tops of the calcite crystals; it shows the well developed upper rhombohedral faces (about 8 μm in size).

In the older quartz–oolitic limestones, cementation is better developed. Sparry calcite cement crystals increase in size (20–30 μm) and grow to fill most of the intergranular pores (Fig. 8D), while the outer rims of some ooids have been changed to sparry calcite. Some micritic peloids have been almost completely recrystallized to sparry calcite (Fig. 8E). All calcareous and non-calcareous grains are entirely covered by fringes of sparry calcite cement.

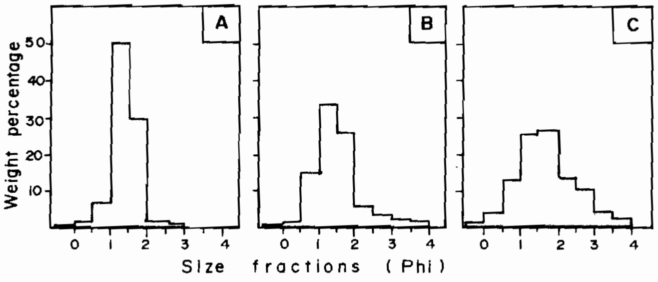

Fig. 7. Histograms of the grain size distribution of the oolitic limestones (A), quartz–oolitic limestones (B) and the insoluble residue of the quartz–oolitic limestones (C).

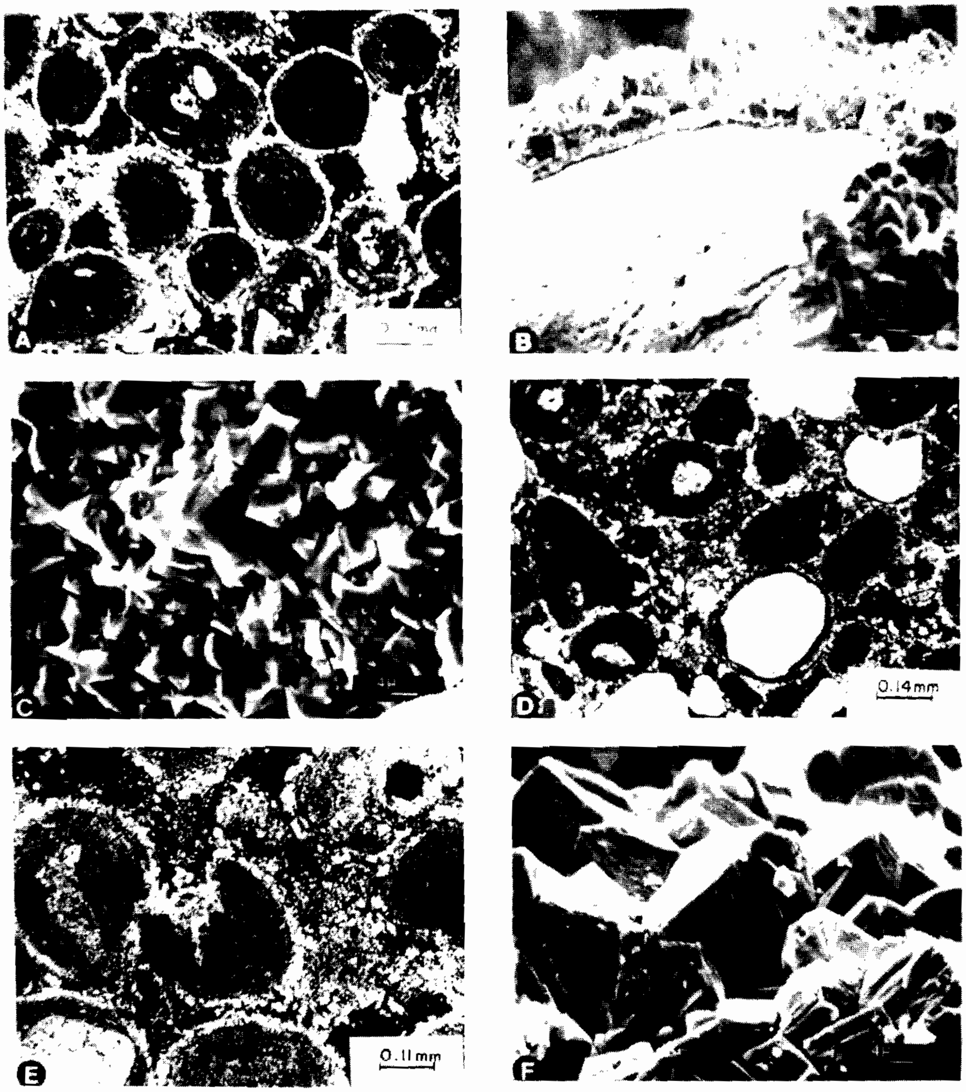

Fig. 8. (A) Photomicrograph of oolitic limestone showing the development of sparry calcite cement on the surface of the framework grains. (B) SEM photomicrograph showing the incipient development of sparry calcite on ooid surface. (C) SEM photomicrograph of a vertical view of calcite cement coating an ooid. Size of the calcite crystals is about 4 μm. (D) Photomicrograph of the quartz–oolitic limestones. Calcite cement is more abundant than in the oolitic limestones. (E) Photomicrograph of quartz–oolitic limestones showing well developed sparry calcite cement. Note partial calcitization of peloids. (F) SEM photomicrograph of calcite cement in quartz–oolitic limestones. Calcite rhombs are coarser than those of the oolitic limestone.

MINERALOGY

X-ray diffraction analysis confirms that the *whole sediment* of the studied samples is chiefly composed of carbonates, quartz and feldspars. Carbonates are represented by aragonite, calcite and high-Mg calcite (Table 3). There are significant differences in the mineralogical composition of both oolitic limestones and quartz–oolitic lime-

Table 3. Mineralogy of the *whole sediments* of the Quaternary oolitic limestone deposits of Al-Doha area, Kuwait, based on X-ray diffraction studies and Sr content

	Carbonates (%)						
Sample No.	Aragonite	Calcite	High-Mg calcite	Total	Quartz (%)	Feldspars (%)	Sr (ppm)
I—Oolitic limestones							
X1	45	40	5	90	5	5	5450
1	45	40	5	90	5	5	4990
A4	45	45	*t*	90	5	5	4790
X2	40	45	5	90	5	5	5380
Y1	35	45	*t*	80	10	10	6270
Y2	35	50	*t*	85	10	5	5570
7	40	55	*t*	95	5	*t*	4750
8	35	40	*t*	75	20	5	3910
Average	40	45	*t*	85	10	5	5139
II—Quartz–oolitic limestones							
9–1	30	45	*t*	75	20	5	4400
9–2	15	40	0	55	35	10	2710
9–3	15	30	*t*	45	45	10	2660
9–4	15	35	0	50	40	10	4050
9–5A	10	20	0	30	65	5	1710
9–5B	10	25	0	35	35	10	2390
Average	15	35	*t*	50	45	5	3002

t: traces.

stones. Non-calcareous minerals, which are mainly represented by quartz and feldspars, constitute about 50% of the whole sediments of the quartz oolitic limestones, whereas they form only about 15% of that of the oolitic limestones. It was also noticed that the calcite/aragonite ratio is about 1·12 in the oolitic limestones and 2·33 in the quartz–oolitic limestones. High-Mg calcite (mostly 14–16 mole% $MgCO_3$) is present in trace amount in all oolitic limestones but is generally absent from the quartz–oolitic limestones. Fig. 9 shows the differences in mineralogical composition.

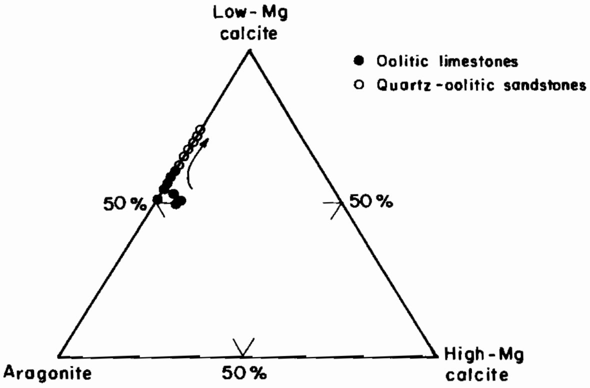

Fig. 9. Mineralogy of Quaternary oolitic sediments from Al-Doha area, Kuwait.

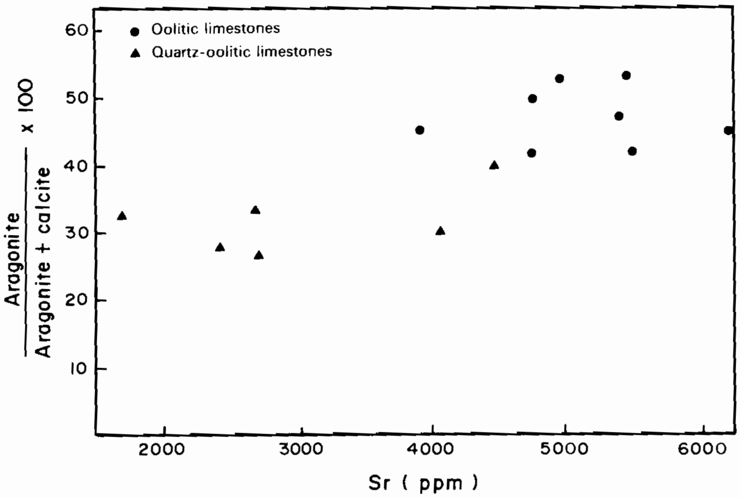

Fig. 10. Relationship between Sr content and aragonite/calcite ratio in the Quaternary oolitic sediments of Al-Doha area, Kuwait.

The strontium content of the sediments ranges from 4990 ppm to 1710 ppm. These values are slightly higher than those of Pleistocene deposits and lower than those of Recent carbonate sediments (Stehli & Hower 1961). Strontium is relatively more abundant in the younger oolitic limestone deposits than in the older quartz–oolitic limestones. It was noticed that strontium content decreases with the decrease of aragonite and the increase of calcite (Fig. 10).

SURFACE TEXTURE OF QUARTZ GRAINS

Surface texture of quartz sand grains has been used to identify the sources and genesis of various detrital sediments (Krinsley *et al.* 1973; Ly 1978; Al-Saleh & Khalaf 1982). In the present study the surface texture of two types of quartz grains from the quartz–oolitic limestones was examined. These are carbonate-coated quartz grains and uncoated (free) quartz grains. The grains examined are generally rounded to subrounded. Free quartz grains are mostly characterized by smooth surfaces with few mechanical pits and abundant dish-shaped depressions (Fig. 11A). Surface texture of these grains is very similar to that described by Al-Saleh & Khalaf (1982) from Recent desert dunes. Signs of chemical etching are also manifest on the surface of these grains in the form of deep grooves (Fig. 11B & C) which are mostly due to the dissolution of quartz along microfractures. Surfaces of the carbonate-coated quartz are characterized by abundance of deeply etched oriented triangular pits (Fig. 11D). This feature indicates the dissolution of silica along the prismatic faces of the quartz grains in an alkaline diagenetic environment.

DISCUSSION

Petrographical and mineralogical characteristics of the oolitic deposits in Al-Doha area allow them to be correlated with the Pleistocene oolitic ridges of Al-Khiran area, south of Kuwait. Picha & Saleh (1977) distinguished four mappable lithostratigraphic

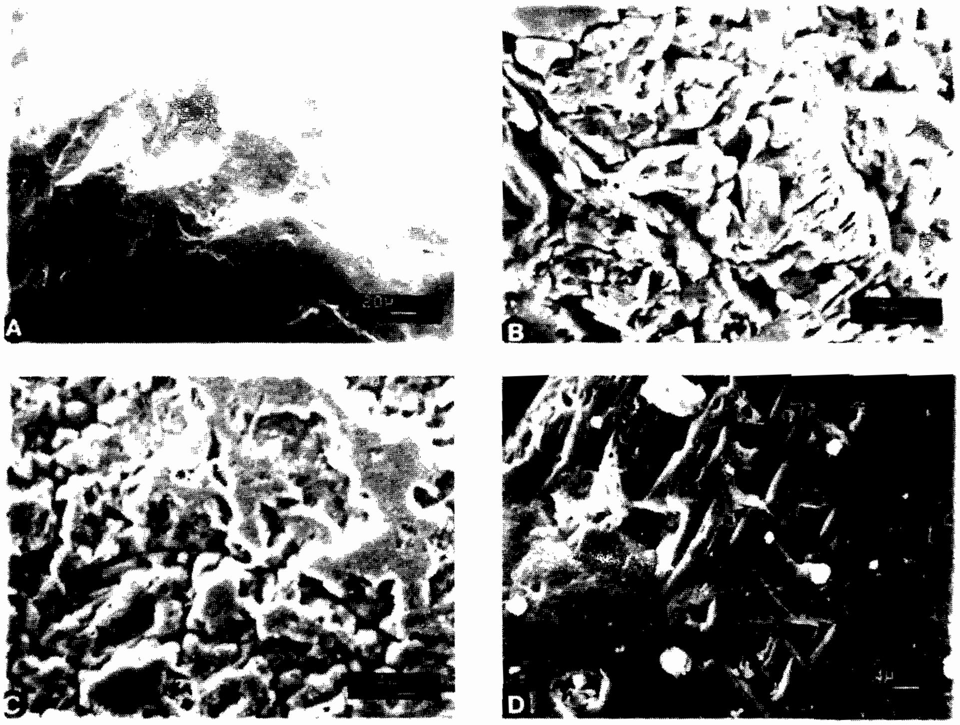

Fig. 11. SEM photomicrographs showing surface features of quartz sand grains. (A) Irregular breakage pattern with abundant dish-shaped depressions. (B) Meandering ridges and dendritic deep grooves. (C) Irregular patchy etching. (D) Deeply etched well oriented triangular pits.

units within the Pleistocene oolitic complex of Al-Khiran area. These are (from top to bottom): (A) younger oolitic limestones, (B) older oolitic limestones, (C) quartz–oolitic limestones, and (D) oolitic quartzose sandstones. The oolitic limestones of Al-Doha are here correlated with the younger and older oolitic limestones of Al-Khiran, while the quartz–oolitic limestones of Al-Doha correlate with the quartz–oolitic sandstones and oolitic quartzose sandstones of Al-Khiran area.

The geological setting and primary composition of the quartz–oolitic limestones unit indicate that it formed during a period of "stand still" following transgression. The deposition of this unit could be contemporaneous with the fluviatile Dibdibba gravels of northern Kuwait, deposited during a fluvial stage of the Pleistocene (Picha 1978; Khalaf *et al.* 1982b). The detrital sandy material that constitutes a considerable portion of the quartz–oolitic limestones is mostly derived from those Pleistocene fluvial deposits. During the marine transgression, these detrital materials were reworked and with the addition of carbonates, the quartz–oolitic limestones developed as a basal sheet. The occurrence of primary carbonates, either as ooids or superficial coatings of detrital material, indicates that although the quartz–oolitic limestones might be contemporaneous with the fluviatile Dibdibba Formation, they appear to have been deposited near the end of the pluvial period and before commencement of the arid phase.

Increase in aridity and the development of a calcareous blanket (quartz–oolitic limestones) over the pre-oolitic detrital deposits eventually led to the deposition of oolitic limestone deposits. It is believed that the oolitic limestones were deposited as foreshore sand bars during a regression phase. The oolitic deposits were then subjected to subaerial diagenetic processes mainly represented by: cementation, alteration of aragonite to calcite, and etching of quartz grains. Two main stages of progressive subaerial diagenesis are distinguished.

1. The first stage is characteristic of the friable oolitic limestones. Ooids are held together by finely crystalline sparry calcite cement (8 μm in size) which grows only near grain contacts. The aragonite composition of the ooids is still preserved. The ratio of calcite to aragonite is about 1. Calcite is present as skeletal fragments and as cement. The strontium content of these deposits is in the range of 4000–6000 ppm, and is similar to the strontium content of Recent marine carbonate sediments. This high strontium content is closely related to the aragonite content, which shows no indication of replacement or dissolution. The calcite cement must have been supplied mostly from outside.

2. The second stage of diagenesis occurs in the more lithified quartz–oolitic limestones. The sparry calcite cement is more abundant than in the previous stage. It generally surrounds the grains and occasionally fills the intergranular pore spaces, and is more coarsely crystalline (about 20–30 μm), as illustrated in Fig. 8F. High-Mg calcite has almost disappeared, and the aragonite cortices of the ooids are partially replaced by neomorphic calcite. The calcite/aragonite ratio is 2·3 and the strontium content is low, in the range 1700-4000 ppm.

The two stages of progressive diagenesis distinguished in the Quaternary oolitic deposits of Al-Doha area can be compared with stages II and III of Land *et al.* (1967) for the skeletal limestones in Bermuda.

The diagenetic features of the studied deposits revealed that the Quaternary oolitic sediments of Al-Doha area are diagenetically immature. This may be mainly attributed to the insufficiency of the meteoric water required to complete the diagenetic development of the deposits.

ACKNOWLEDGEMENTS

The authors are especially grateful to the technicians of the Department of Geology, University of Kuwait, and the Kuwait Institute for Scientific Research, for preparation of samples. Special thanks are due to Professor D. Shearman of the Geology Department, Imperial College, London, Professor D. Almond and Dr A. Gunatilaka, of the Geology Department, Kuwait University, for their valuable assistance in proofreading the manuscript.

REFERENCES

Al-Saleh, S. & Khalaf, F.I. 1982. Surface texture of quartz grains from various recent sedimentary environments in Kuwait. Journal of Sedimentary Petrology **52**: 215–25.

Carver, R.E. 1971. Procedures in sedimentary petrology. Wiley Interscience, New York, 653 pp.

Folk, R.L. 1974. Petrology of sedimentary rocks. Hemphill Publication Co., Austin, Texas, 182 pp.

Folk, R.L. & Ward, W.L. 1957. Brazos river bar, a study in the significance of grain size parameter. Journal of Sedimentary Petrology **27**: 3–27.

Friedman, G.M. 1964. Early diagenesis and lithification in carbonate sediments. Journal of Sedimentary Petrology **34**: 777–813.

Fuchs, F., Gattinger, T.E. & Holzer, H.F. 1968. Explanatory text to the synoptic geologic map of Kuwait. Geologic Survey of Austria, Vienna, 87 pp.

Gavish, E. & Friedman, G.M. 1969. Progressive diagenesis in Quaternary to late Tertiary carbonate sediments: sequence and time scale. Journal of Sedimentary Petrology **39**: 980–1006.

Gross, M.G. 1964. Variations in the O^{18}/O^{16} and C^{13}/C^{12} ratios of diagenetically altered limestones in the Bermuda Island. Journal of Geology **72**: 170–94.

Khalaf, F.I. & Ala, M. 1980. Mineralogy of tidal flat muddy sediments of Kuwait, Arabian Gulf. Marine Geology **35**: 331–42.

Khalaf, F.I., Al-Bakri, D. & Al-Ghadban, A. 1984. Characteristics of surficial sediments of Kuwait, Arabian Gulf. Sedimentology **31**: 531–45.

Khalaf, F.I., Al-Ghadban, A., Al-Saleh, S. & Al-Omran, L. 1982a. Sedimentology and mineralogy of Kuwait Bay bottom sediments, Kuwait, Arabian Gulf. Marine Geology **46**: 71–99.

Khalaf, F.I., Gharib, I.M. & Al-Kadi, A.S. 1982b. Sources and genesis of the Pleistocene gravelly deposits in northern Kuwait. Sedimentary Geology **31**: 101–17.

Krinsley, D.H., Biscaye, P.R. & Turekian, K.K. 1973. Argentine basin sediment sources as indicated by quartz surface textures. Journal of Sedimentary Petrology **43**: 251–57.

Land, L.S. 1967. Diagenesis of skeletal carbonates. Journal of Sedimentary Petrology **37**: 914–30.

Land, L.S., Mackenzie, F.T. & Gould, S.J. 1967. Pleistocene history of Bermuda. Bulletin of the Geological Society of America **78**: 993–1006.

Ly, Ch. K. 1978. Grain surface features in environmental determination of late Quaternary deposits in New South Wales. Journal of Sedimentary Petrology **4**: 1219–26.

Macfadyen, W.A. 1938. Water supplies in Iraq. Iraq, Geological Department, Publication No. 1, Baghdad.

Milton, D.I. 1967. Geology of the Arabian Peninsula, Kuwait. U.S. Geological Survey Professional Paper **560-F**: 1–7, Washington.

Owen, R.M. & Nasr, S.N. 1958. Stratigraphy of the Kuwait–Basra area. In: Habitat of oil. Symposium of the American Association of Petroleum Geologists: 1252–78.

Picha, F. 1978. Depositional and diagenetic history of Pleistocene and Holocene oolitic sediments and sabkhas in Kuwait, Persian Gulf. Sedimentology **25**: 427–50.

Picha, F. & Saleh, A.A. 1977. Quaternary sediments in Kuwait. Journal of the University of Kuwait (Science) **4**: 169–85.

Purser, B.H. (Ed.) 1973. The Persian Gulf. Holocene carbonate sedimentation and diagenesis in a shallow epicontinental sea. Springer-Verlag, Berlin, Heidelberg, New York, 417 pp.

Saleh, A.A. 1975. Pleistocene and Holocene oolitic sediments in the Al-Khiran area, Kuwait. Unpublished M.Sc. thesis, University of Kuwait, 125 pp.

Salman, A. 1979. Geology of the Jal-Al-Zor–Al-Liyah area, Kuwait. Unpublished M.Sc. thesis, University of Kuwait, 129 pp.

Selim, A.A. 1974. Origin and lithification of the Pleistocene carbonates of the Salum area, western coastal plain of Egypt. Journal of Sedimentary Petrology **44**: 70–78.

Sproule, J.C. & Associates Ltd. 1974. Phase A report. Sources of construction materials. Prepared for Ministry of Commerce and Industry, State of Kuwait, 125 pp.

Stehli, F.G. & Hower, J. 1961. Mineralogy and early diagenesis of carbonate sediments. Journal of Sedimentary Petrology **31**: 358–71.

(*Received 3 November 1984, revised 20 January 1985*)

بتروجرافية ونمط تصخر رواسب
الحجر الجيري السرئي التابعة للحقب الرباعي في شمال الكويت

فكري ابراهيم خلف
ادارة العلوم البيئية والأرضية ،
معهد الكويت للأبحاث العلمية

على عبد الله الشملان
قسم الجيولوجيا
بجامعة الكويت

محمد ابراهيم السيد
ادارة العلوم البيئية والأرضية ،
معهد الكويت للأبحاث العلمية

خلاصة

تم التعرف على حزمين من رواسب الحجر الجيري السرئي التابعة للحقب الرباعي في منطقة الدوحة شمال دولة الكويت . وقد بينت الدراسة امتداد الحزم الأول في اتجاه شرق ـ غرب على طول الساحل ، ثم يتبعه جنوبا الحزم الثاني وهو أقدم من الحزم الأول ، حيث يغطى رواسب ما قبل الحقب الرباعي . تتكون رواسب الحزم الأول أساسا من تجمعات سرئانية وقليل من التجمعات الحبيبية الطينية وكسارة المحار وحبيبات الكوارتز ، وقد سمي حزم الحجر الجيري السرئي . أما رواسب الحزم الثاني فهي تتكون كذلك من تجمعات سرئانية بصفة رئيسية ، الا أن نسبة تواجد حبيبات الكوارتز وكسارة المحار بها أكثر من تلك المتواجدة في رواسب الحزم الأول ، وقد سمي حزم الحجر الجيري السرئي الكوارتزي . وقد لوحظ أن رواسب حزم الحجر الجيري السرئي الكوارتزي أكثر تلاحما من رواسب حزم الحجر الجيري السرئي ، حيث يزداد حجم بلورات معدن الكالسيت وتملأ معظم الفراغات بين الحبيبات . كما لوحظ أيضا أن بعض التجمعات الحبيبية الطينية الميكريتية قد أعيد تبلورها كاملا الى بلورات الكالسيت السباري ، كما تتغطى بعض التجمعات الحبيبية الطينية بجدار رقيق من بلورات الكالسيت السباري . هذا ويمكن مضاهاة رواسب حزم الحجر الجيري السرئي في منطقة الدراسة برواسب الحجر الجيري السرئي القديم والحديث في منطقة الخيران ، ومضاهاة الحجر الجيري السرئي الكوارتزي في منطقة الدراسة برواسب الحجر الرملي السرئي الكوارتزي والحجر الرملي الكوارتزي السرئي في منطقة الخيران . وقد تبين أن الرواسب السرئية في منطقة الدوحة غير كاملة التصخر ، ويعزى ذلك لقلة المياه السطحية والتي تعتبر من المتطلبات الرئيسية لترسيب المعادن اللاحمة ومن ثم استكمال عملية التصخر .